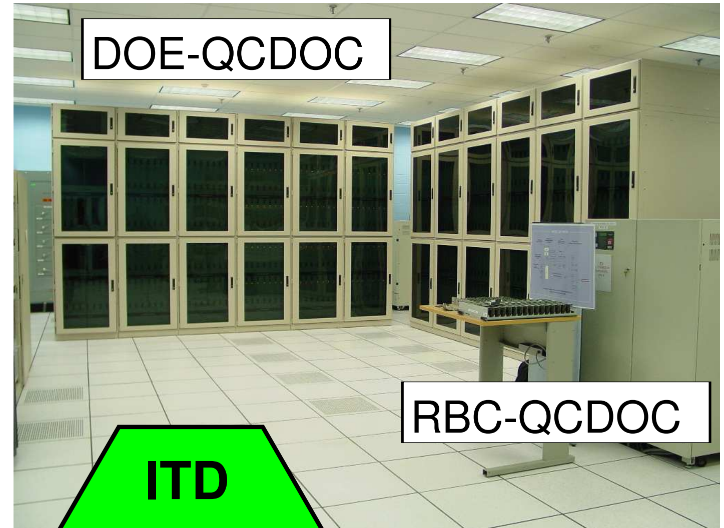
The Lattice Gauge Theory Group at BNL

(established 02/2005)

- The LGT group and the BNL environment
- Research topics of the LGT group
- Research activities in 2005/06
- Plans for the near future
- Conclusions

Lattice Gauge Theory @ BNL



RHIC

RIKEN BNL

ITD QCDOC

LGT
hot&dense QCD

NT
heavy ion phenomenology

HEP
LGT&particle physics

Collaborations

- Columbia Univ.
- Bielefeld Univ.
- LGT Consortium
- LA, Tokyo, Wroclaw,..

New Computing Resources

BlueGene/L

- BNL/SBU center
- Livermore
- Argonne (BG/P)

LGT group provides theoretical support for the experimental heavy ion program at BNL

The lattice group at BNL

group leader (tenure): Frithjof Karsch

2 Assistant Scientists:

Saumen Datta (until 09/06 $\Rightarrow$ tenure at TIFR, Mumbai)

$\Rightarrow$ Shinji Ejiri (from Tokyo University), starting 10/06

Peter Petreczky (joint appointment with RIKEN/BNL)

5 Research Associates:

Christian Schmidt (from Wuppertal University, Germany)

Takashi Umeda (from Kyoto University, Japan)

Felix Zantow (leaves this month)

$\Rightarrow$ Wolfgang Soeldner (from Bielefeld University), starting 09/06

Claudio Pica (from Pisa University), starting 10/06

N.N. (LDRD project 'QCD on BlueGene'), starting 10/06

0.5 secretariat: A. Aponte

The lattice group at BNL (cont’d)

Shinji Ejiri
Frithjof Karsch
Peter Petreczky
Claudio Pica
Christian Schmidt
Wolfgang Soeldner
Takashi Umeda
N.N. (expected 10/06)

collaborator at RIKEN/BNL

Masakiyo Kitazawa
Agnes Mocsy

SciDAC funded QCDOC support

Chulwoo Jung

PhD students:

Michael Cheng (Columbia)
Matthias Döring (Bielefeld)
Kay Hübner (Bielefeld)

Research Activities of the Group

- QCD thermodynamics
  - equation of state and critical temperature 1
  - thermodynamics at non-zero baryon number density 1
  - Charge fluctuations and baryon number correlations 1
  - structure of the QCD phase diagram
- In-medium properties of hadrons
  - light quark sector: χSB and thermal dilepton rates
  - heavy quark sector: deconfinement and quarkonium 4
  - Hadrons at $T \neq 0$ and QCD with dynamical light quarks
- Software development and the next generation of computers for LGT calculations (QCDOC, apeNEXT, BlueGene

publication in refereed journals in 2005/06
(+ 21 conference contributions/reviews)

Research Plan 2006 - 2009

– currently pursued research –

- QCD thermodynamics
  - equation of state and critical temperature
  - thermodynamics at non-zero baryon number density
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  - light quark sector: χSB and thermal dilepton rates
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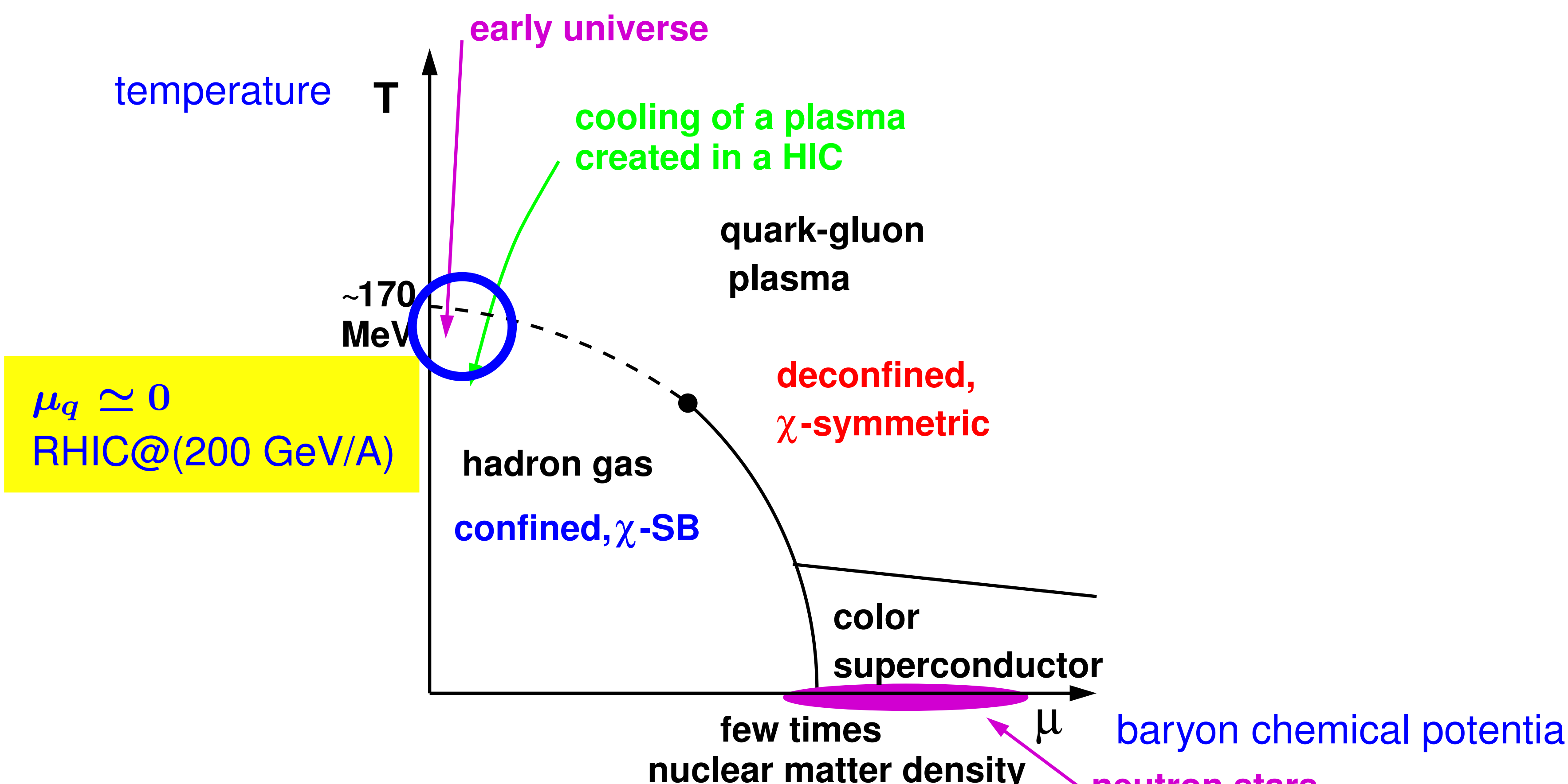
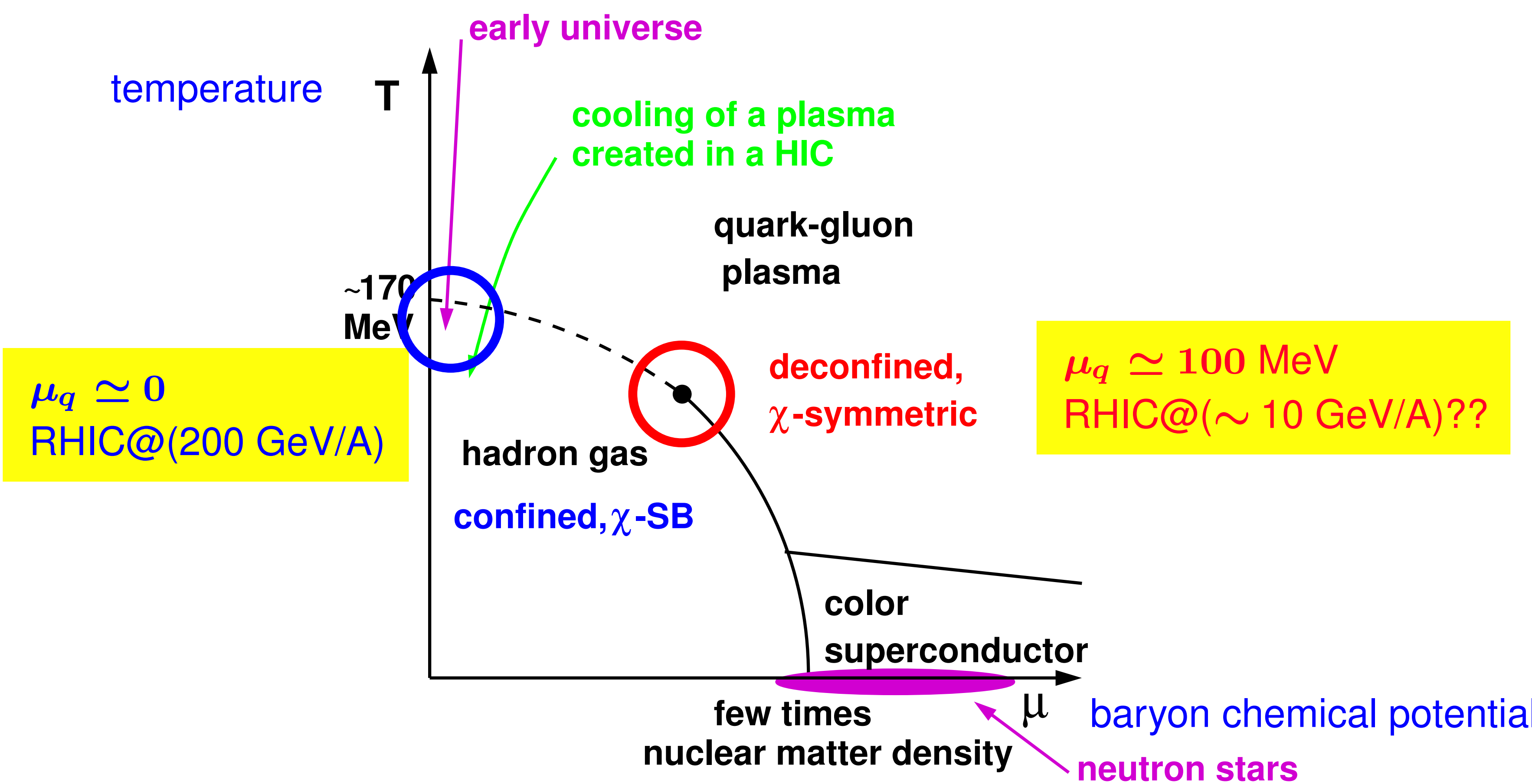
- Software development and the next generation of computers for LGT
- The unexpected...$\Rightarrow$ RHIC at low energies

Phase diagram of strongly interacting matter



Phase diagram of strongly interacting matter

RHIC at low energy $\Leftrightarrow$ LGT at non zero chemical potential



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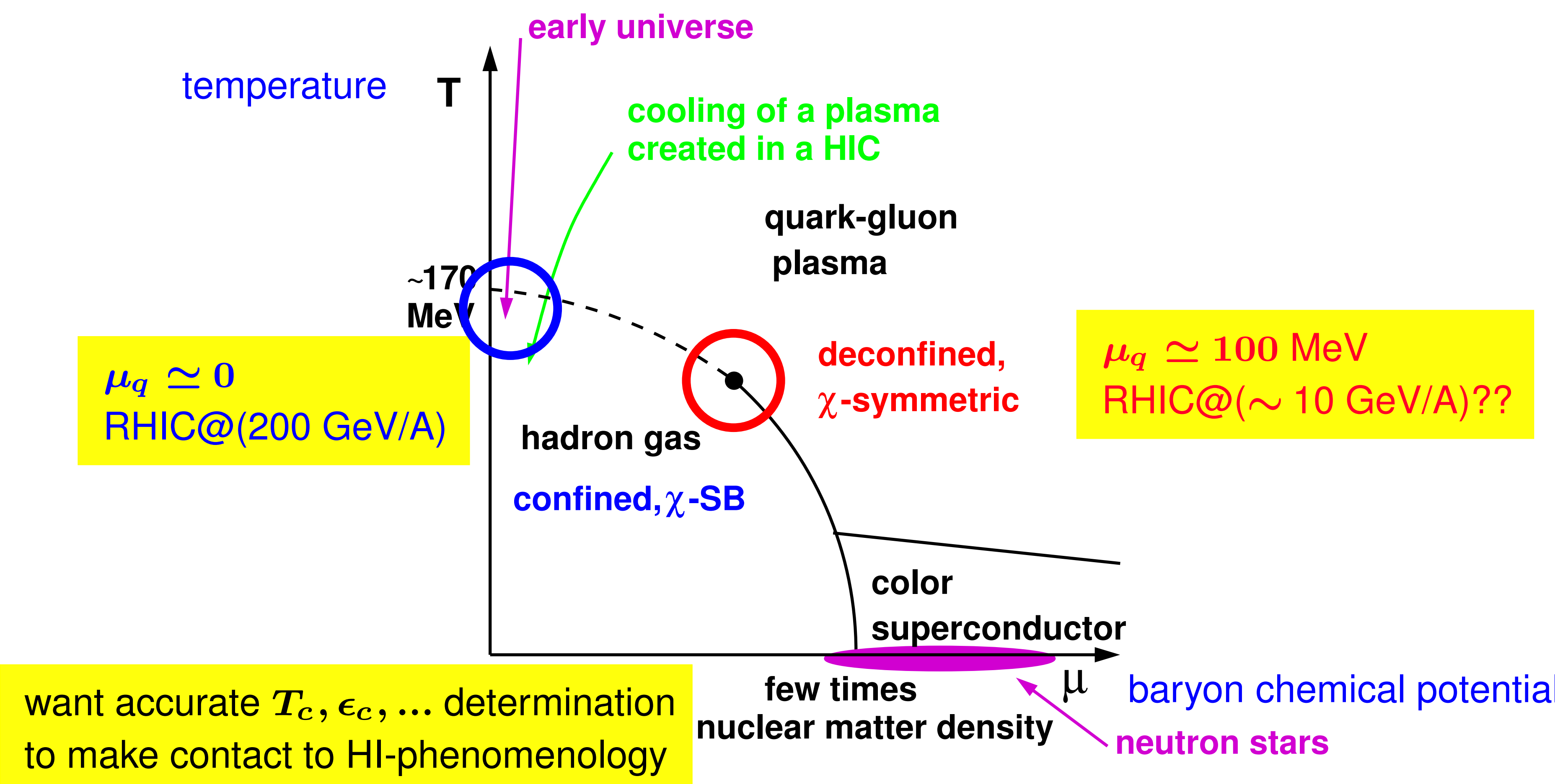
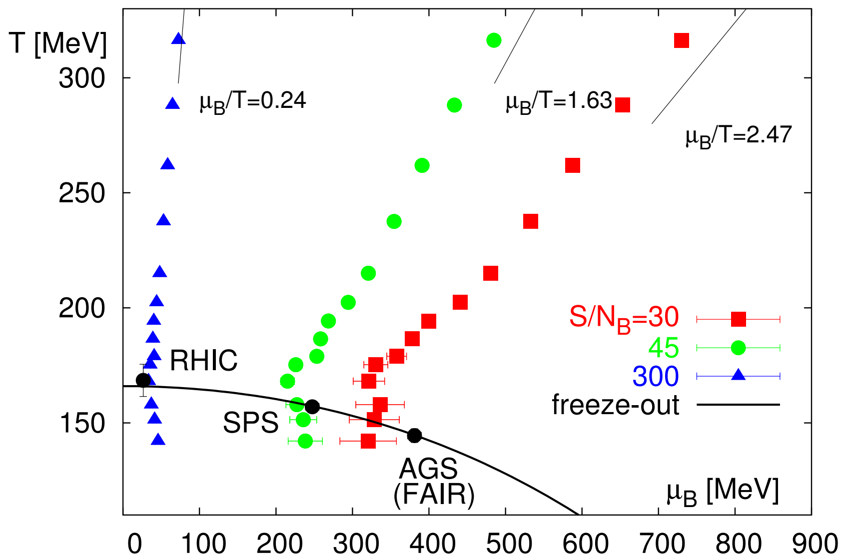
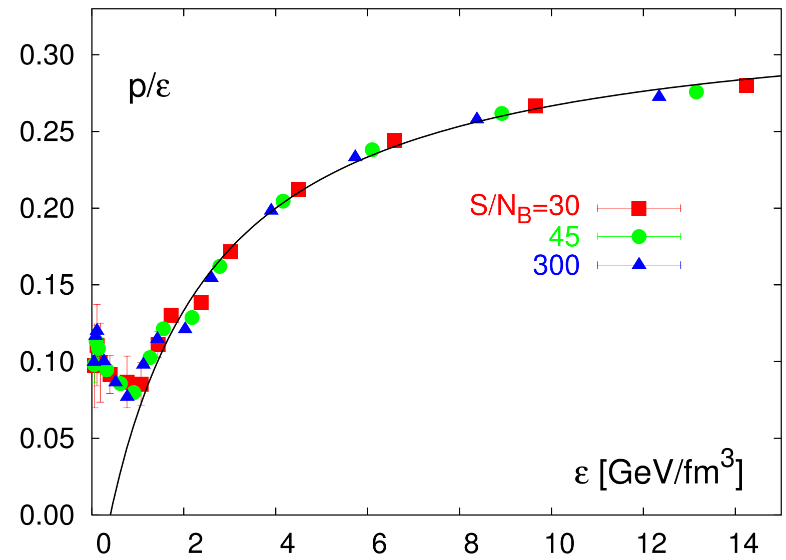


Isentropic Equation of State: p/ϵ

S. Ejiri, F. Karsch, E. Laermann and C. Schmidt, Phys. Rev. D73 (2006) 054506





- p/ϵ vs. ϵ shows almost no dependence on S/N_B
- softest point: $p/\epsilon \simeq 0.075$
- phenomenological EoS for $T_0 \lesssim T \lesssim 2T_0$

$$\frac{p}{\epsilon} = \frac{1}{3}\left(1 - \frac{1.2}{1 + 0.5\ \epsilon\ \mathrm{fm}^3/\mathrm{GeV}}\right)$$

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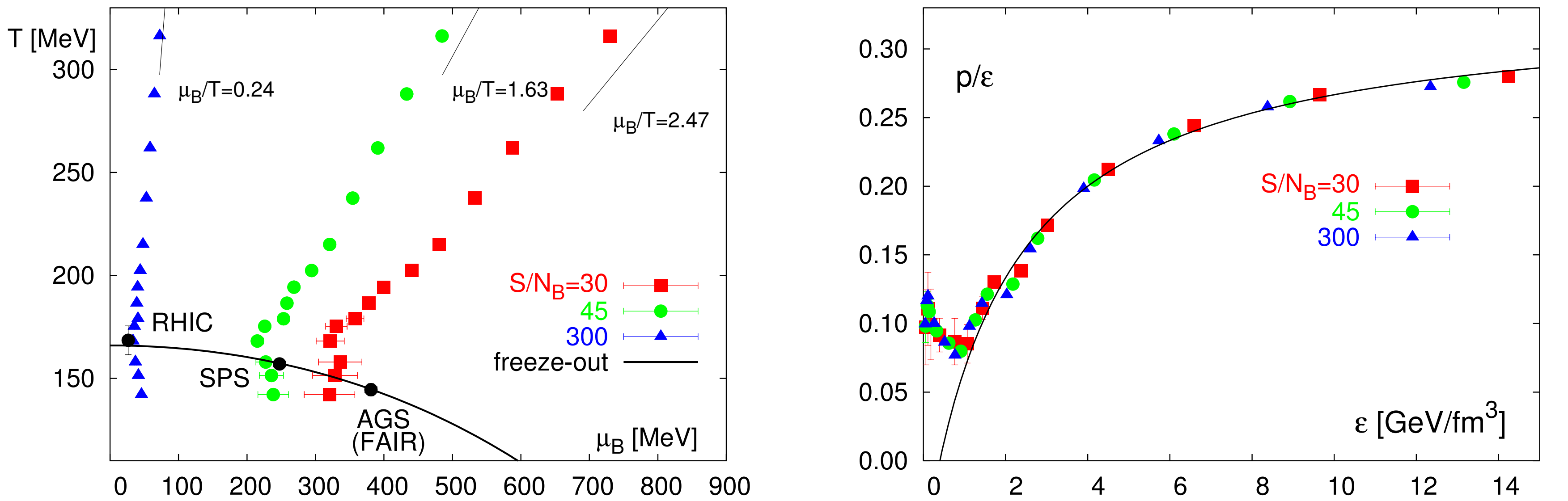

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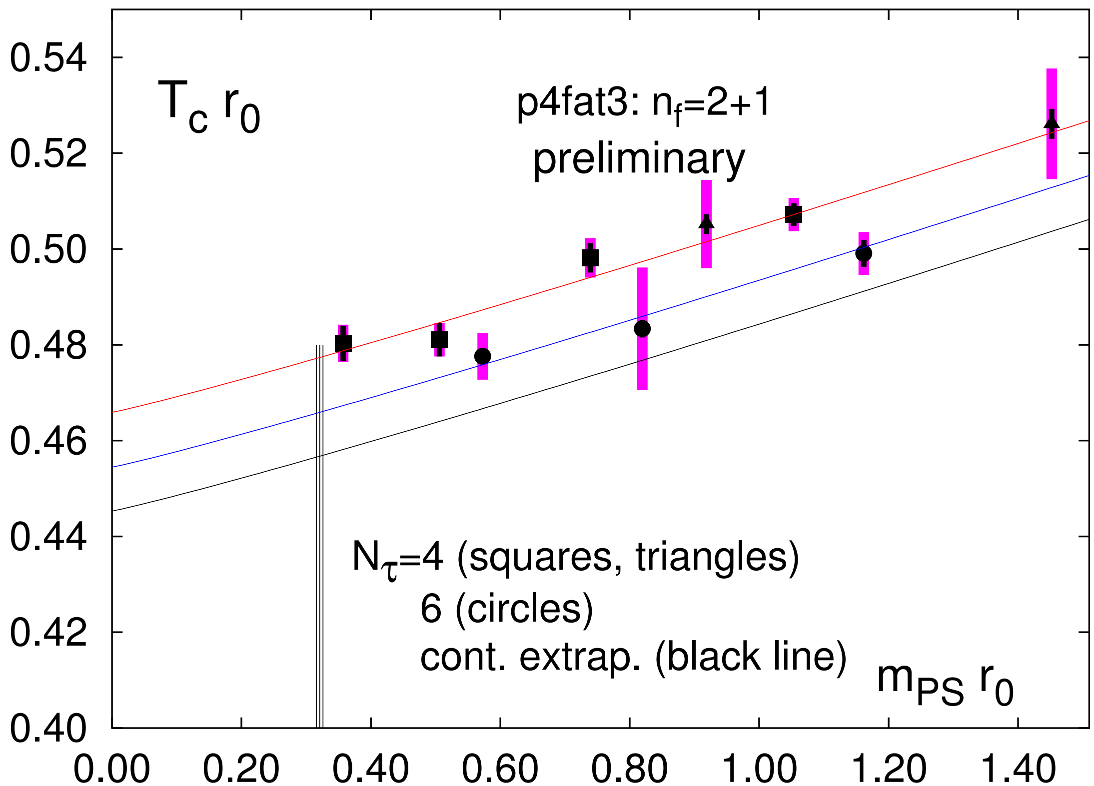
awaits confirmation in (2+1)-flavor QCD with light quarks

A new determination of the transition temperature in QCD

- calculation of transition temperature with almost physical quark masses and different lattice cut-off values

$\Rightarrow$ extrapolation to physical limit ($m_\pi = 135$ MeV) and continuum limit ($a \to 0$)



RIKEN-BNL-Columbia-Bielefeld collaboration, in preparation.

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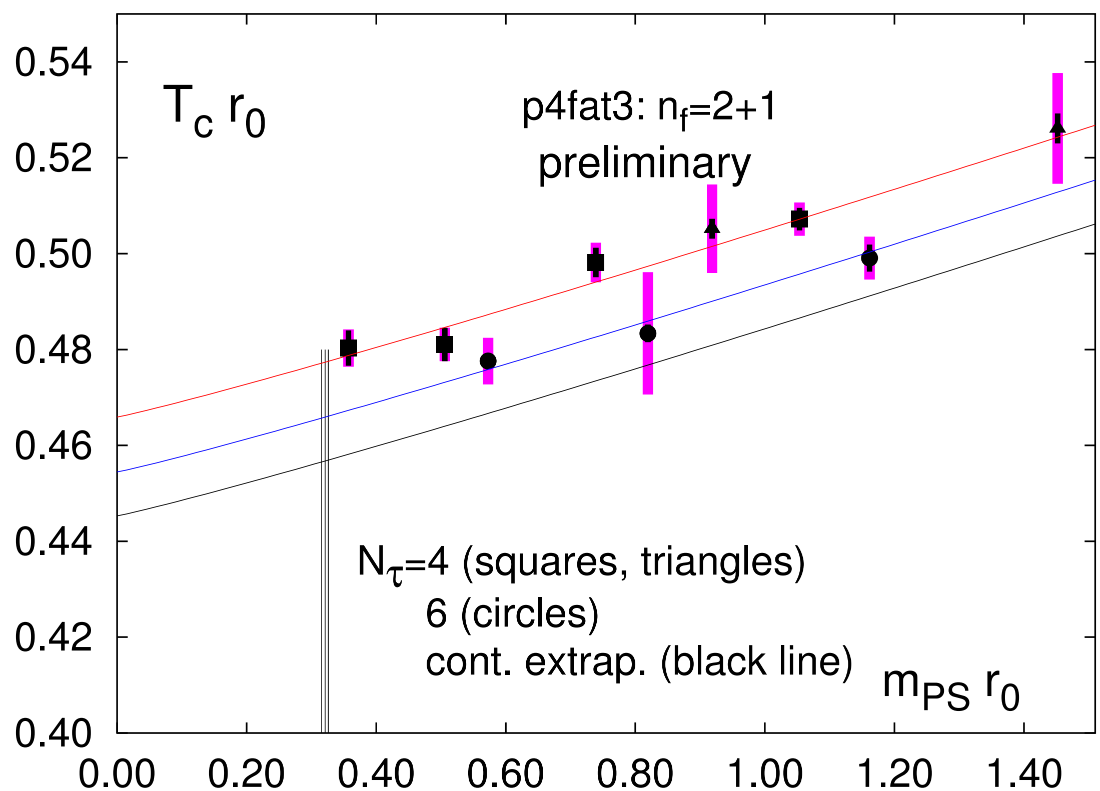

$\sqrt{\sigma} \simeq 465$ MeV

$r_0 = 0.469(7)$ fm

$\Downarrow$

$T_0 \simeq 192(5)(4)$ MeV

preliminary

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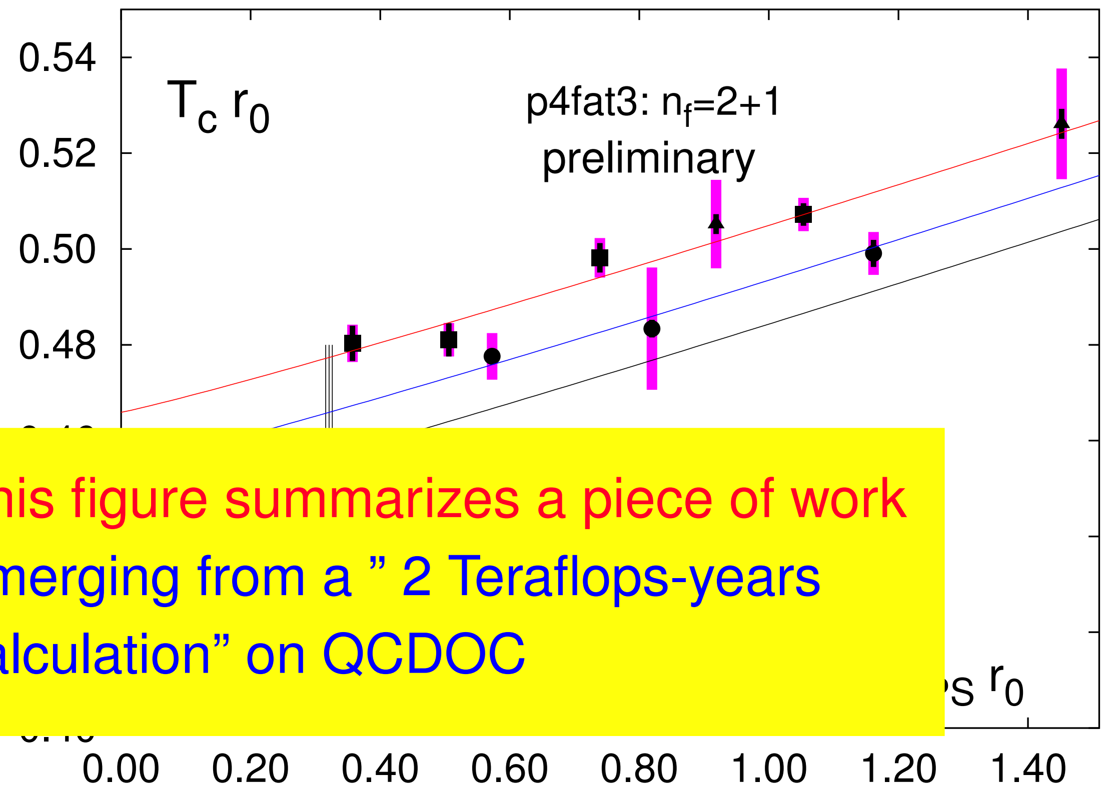

This figure summarizes a piece of work emerging from a " 2 Teraflops-years calculation" on QCDOC

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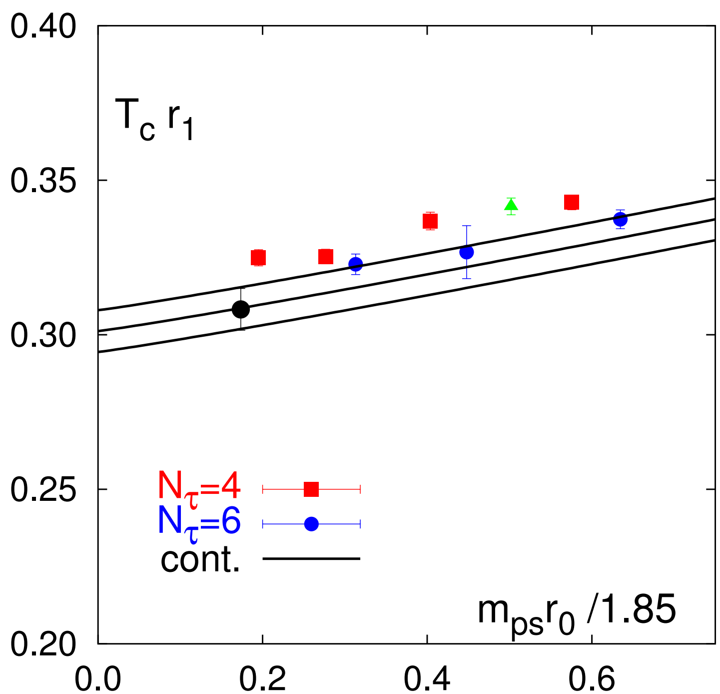
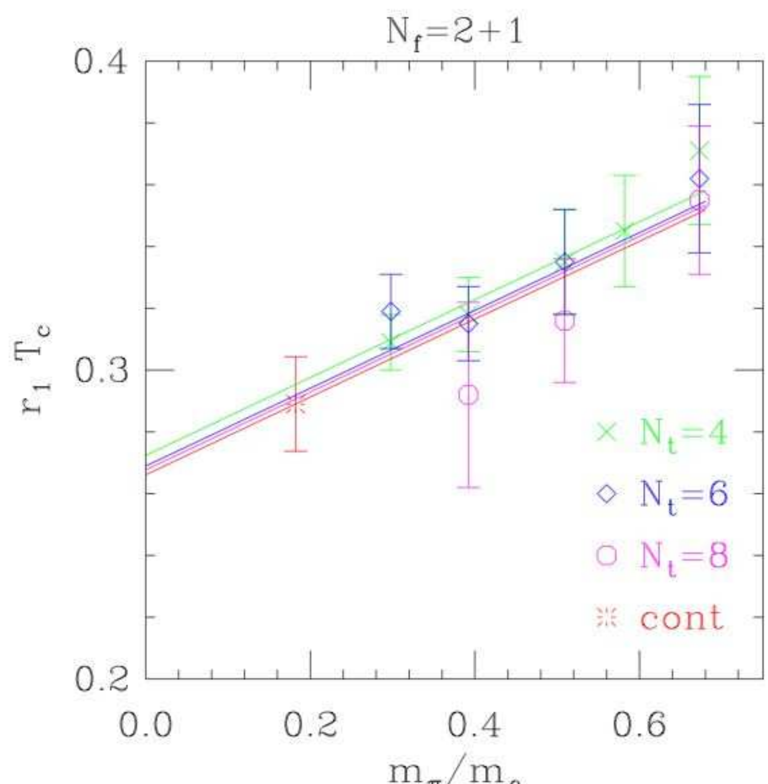


RIKEN-BNL-Columbia-Bielefeld



MILC, PRD71 (2005) 034504
(figure unpublished)

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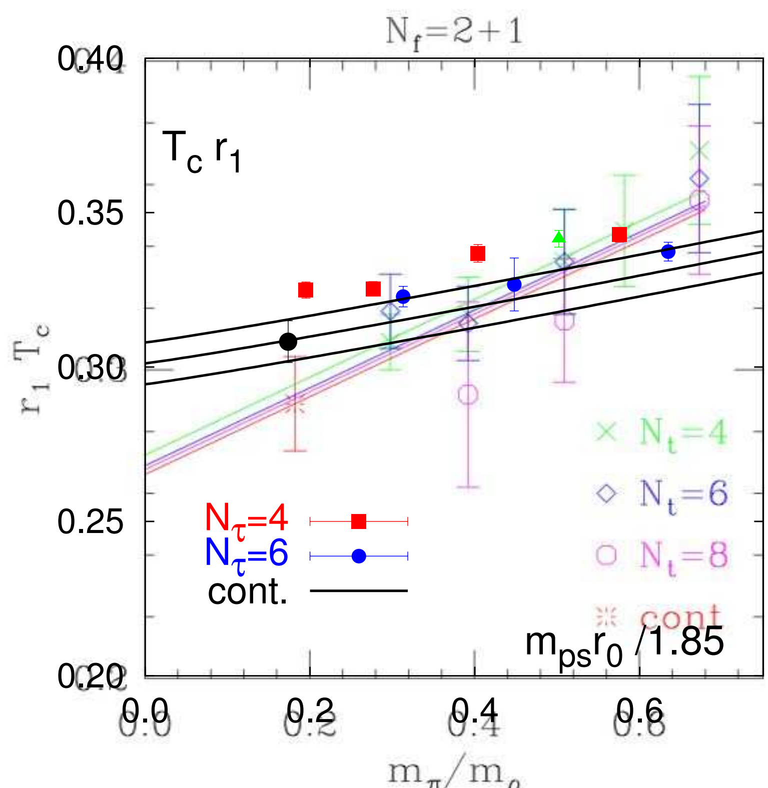

RIKEN-BNL-Columbia-Bielefeld

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- freeze-out conditions at RHIC from particle yields:
  STAR, PHENIX white papers (Nucl. Phys. A **757** (2005) 102 and 184)
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  - $T_{freeze} < 170$ MeV

$\Rightarrow$ need to think about a strongly interacting hadronic regime before freeze-out ($\Delta T \sim (20-30)$ MeV $\Rightarrow$ a few Fermi lifetime)

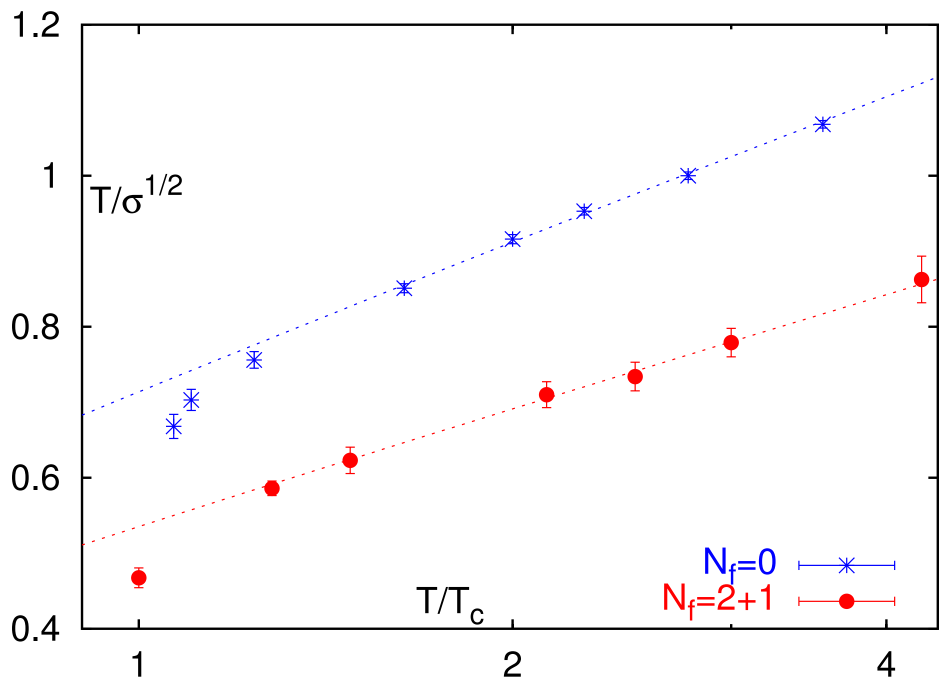
$\Rightarrow$ challenge for hydro modeling

Spatial String Tension:
..coupling constant at high-T

RIKEN-BNL-Columbia-Bielefeld collaboration, in preparation

- Is the coupling strong in the QGP?
  - spatial string tension: $\sqrt{\sigma_s} = c\, g^2(T)\, T$

    probes concepts of dimensional reduction used in pert. theory
    - "c" can be determined in 3-d SU(3) gauge theory,
    - "c" is expected to be flavor independent



2-loop running of the coupling starts already at $T \gtrsim 2T_c$

$c = 0.566(13)$ (SU(3))

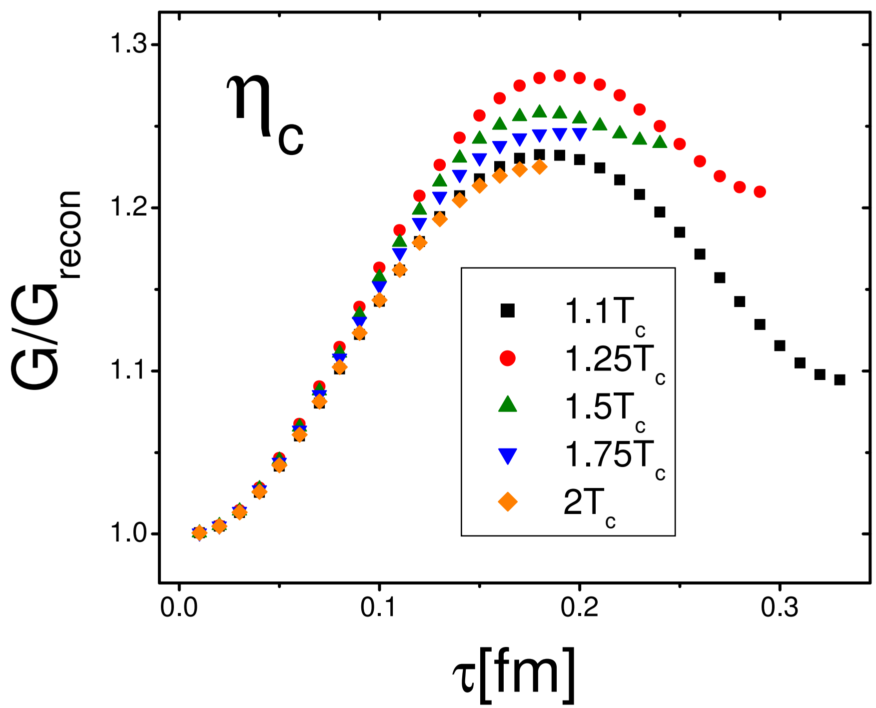
$c = 0.587(41)$ (QCD)

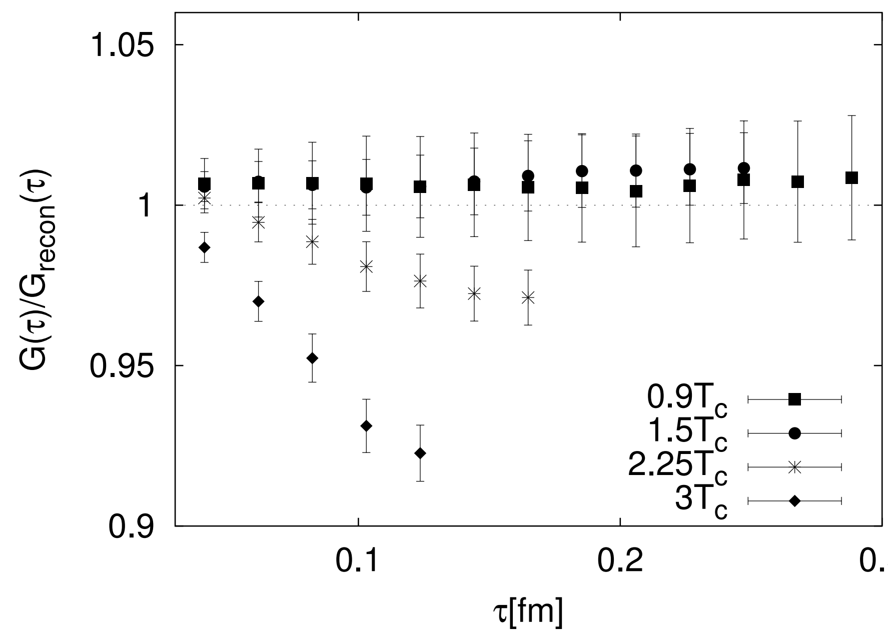
Quarkonium at high temperature:
Potential models vs. Lattice results

P. Petreczky and A. Mocsy, Phys. Rev. D73 (2006) 074007

- a comparison of lattice results for the quarkonium correlation functions at high temperature with correlators constructed from potential model motivated spectral functions

$\Rightarrow$ need a more sophisticated ansatz; threshold effects become important?





Preparation for new projects on BlueGene/L

Modeling the QCD equation of state on BlueGene/L
joint project with LANL, LLNL and MILC collaboration on the Livermore BlueGene/L (R. Gupta, R.Soltz (PIs))

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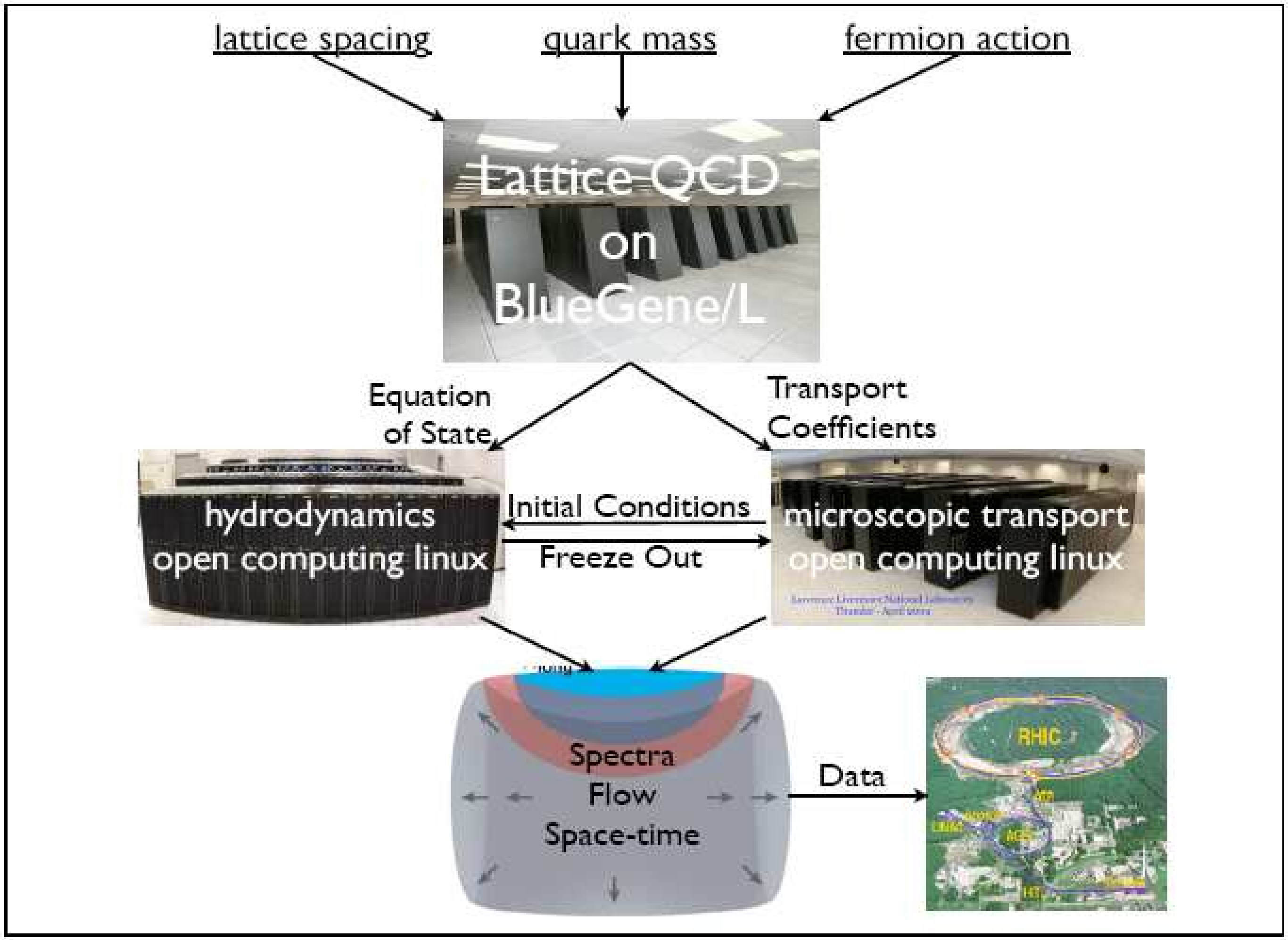

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- T_c, EoS on $N_\tau = 8$ lattices with light dynamical quarks:
  (2+1)-flavor QCD, close to physical m_π / m_K ratio;
  exploring the continuum limit: $N_\tau = 4,\ 6,\ 8$
  analyzing the thermodynamic limit: $V \simeq 500\ \mathrm{fm}^3$

EoS on $32^3 \times 8$ lattices; CPU-time: $\sim$ (20-40) TFlops-years

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- In-medium hadron properties, charmonium, dilepton/photon rates:
  quenched QCD on fine lattices ($a \simeq 0.02\ \mathrm{fm}$);
  analyzing light quark mesons with improved fermion formulations;
  exploring infra-red sensitivity of dilepton rates;
  analyzing charmonium spectra and colored bound state (sQCD fluid?);

  $\Rightarrow$ lattice sizes up to: $128^3 \times 32$; CPU-time: $\sim$ 5 TFlops-years

software development for BG/L at BNL, LDRD project

Schools, workshops, conferences

Members of the LGT-group organized/co-organized several international meetings:

- Heavy Ion Phenomenology, 2-week international graduate school, Bielefeld, Sept. 19-30, 2005, organizers: F. Karsch, D. Schiff (Paris)
- Strong and Electroweak Matter, International conference, BNL, May 10-13, 2006, organizers: F. Karsch, D. Kharzeev, R. Venugopalan
- 4th Workshop on Quarkonium, BNL, June 27-30, 2006, organizers: D. Kharzeev, A. Mocsy, P. Petreczky, T. Ullrich
- QCD in Extreme Conditions, International workshop, BNL, July 31 - Aug. 2, 2006, organizers: S. Datta, R. Pisarski, P. Petreczky and C. Schmidt

Conclusions

- The new LGT group at BNL had a perfect start:
  It is fully integrated in the BNL environment
- The computing resources at BNL (QCDOC) and the well established international collaborations of the group allow to perform research on QCD thermodynamics at the forefront of the field during the next years
- Now is the time to start thinking about ”life after QCDOC”

  $\Rightarrow$ BlueGene/L at BNL (and Livermore), ... BlueGene/P